4S82z

4MOST Stripe 82 redshift survey

A community survey proposal to the 4MOST consortium
Motivation

Explore the nature of dark matter and dark energy

Connect galaxies and black holes to dark matter halos

Trace galaxy and AGN evolution and the role of environment
Key science goals

- Cosmology and astrophysics constraints with joint analysis of cosmic shear, galaxy-galaxy lensing and galaxy clustering.

- Galaxy-halo connection and SMBH-halo connection with joint analysis of lensing, galaxy clustering and abundance.

- Census of stellar mass assembly and star formation history on a full range of scales from cluster core to the general field.

- A multi-λ census of SMBH accretion and co-evolution with host galaxies.
Why Stripe 82?

- Extremely rich set of deep multi-λ imaging data from X-ray to radio, unparalleled among extragalactic fields of comparable size (>~100 deg²). Unique in having both the statistical power and extensive moderate to deep multi-λ coverage.

- High density of existing spectroscopy (SDSS, DEEP2, VVDS, PRIMUS, Wigglez, BOSS, eBOSS, etc.) and a lot more to come (HETDEX, PFS, etc.) over the next few years. 4S82z will fill in an important gap.

- Multi-epoch optical and radio surveys giving detailed variability information.
Our starting point:

The Hyper Suprime-Cam (HSC) SSP Survey

Largest étendue of all existing wide-field optical imaging cameras, not to be surpassed until LSST.

Deep imaging data (grizy) down to $r = 26$ mag (in the wide layer) over 1,400 deg$^2$, much deeper than DES (5000 deg$^2$) and KiDS (1,500 deg$^2$).

Superb image quality (routinely 0.6” FWHM), better than DES (~0.9”) and KiDS (~0.75”).
Our starting point:

The Hyper Suprime-Cam (HSC) SSP Survey

Spring equatorial field: 08:30 < RA < 15:00, -2° < DEC < +5° (680 deg²)

Fall equatorial field: 22:00 < RA < 02:40, -1° < DEC < +7° (630 deg²)
Within the HSC fall equatorial field, the Spitzer-IRAC Equatorial Survey (SpIES) covers 110 deg², and there exist unparalleled multi-λ data from X-ray to radio:

- Soft and hard X-ray from XMM and Chandra over 31.3 deg²
- FUV and NUV from GALEX (twice the depth of Medium Imaging survey, 23.75 mag)
- HSC grizy down to r = 26.1 mag (also shallower optical data from SDSS, DES, etc.)
- NIR (J, Ks) down to 22 mag from VICS82
- MIR IRAC (3.6 and 4.5 μm) from SpIES
- FIR and sub-mm imaging (250, 350 and 500 μm) from Herschel programs (HeRS & HELMS)
- Millimetre (1100, 1400, 2000 μm) observations from ACT & ACTPol
- VLA radio 21,000 (L-band) and 30,000 (S-band) over 80 deg²
And a lot of existing spectroscopy, thanks to extensive spectroscopic campaigns and surveys such as PRIMUS, VVDS, Wiggle-Z, DEEP2
And a lot of existing spectroscopy:

And a lot more to come over the next few years!

HETDEX will measure redshifts for $\sim 300,000$ LAEs from $1.9 < z < 3.5$ and $\sim 300,000$ OII emitters from $0 < z < 0.5$, over our chosen field.

The Subaru Prime Focus Spectrograph (PFS) will measure $\sim 7$ million OII emitters from $0.6 < z < 2.4$ over 1400 deg$^2$ ($\sim 600,000$ over our chosen field).
Survey parameters of 4S82z

Selection: $J < 21.4$ mag (AB)
Redshift range: $0.2 < z < 0.6$
Density: $\sim 8,000$ per deg$^2$
Area: $110$ deg$^2$
RA: $-30^\circ < \alpha < 35^\circ$
DEC: $-0.85^\circ < \delta < 0.85^\circ$
Volume: $\sim 0.1$ Gpc$^3$
Total number of targets: $\sim 0.9$ million

Actual number of targets: $\sim 0.5$ million
Combined number of sources: $\sim 2$ million
4S82z in context

J < 21.4 equivalent to i < 22.25
4S82z in context

The diagram illustrates the density of redshifts against the area in degrees squared for various surveys. The 4S82z star is highlighted, indicating its context within the existing and ongoing surveys. The surveys are color-coded as follows:
- Blue: WAVES
- Black: Existing
- Green: Ongoing
- Red: Future

Surveys include:
- WAVES
- Deep3
- VVDS-D
- VUDS
- VANDELS-SF
- VANDELS-LBG
- VANDELS-passive
- zCOSMOS
- hCOSMOS
- Deep2
- DEVILS
- VIPERS
- PFS-highz
- PFS-lowz
- WAVES-Deep
- MOONS-W
- WAVES-Wide
- DESI-BGS
- GAMA
- 2dFGRS
- SDSS
- Taipan
- 6dFGS

The diagram shows a range of redshift densities from 10 to 10^5. The area covered ranges from 10^0 to 10^4 degrees squared.
4S82z in context

taking into account existing and planned spectroscopy
4S82z in context

Combined with spectroscopy targeting higher z sources

combined power

actual cost
Key science goal
- the nature of dark matter and dark energy

Joint analysis of tomographic **cosmic shear** (correlating the observed shapes of gals over 450 deg$^2$ of KiDS imaging data), **galaxy-galaxy lensing** (correlating the positions of foreground GAMA gals with the shapes of background KiDS gals over 180 deg$^2$), and **galaxy clustering**.

Lift degeneracies and improve constraints on cosmological parameters.

E. van Uitert et al. (2018)
Key science goal
- the nature of dark matter and dark energy

HSC will cover 1400 deg2 with deeper and better quality imaging and one of the best wide-field WL shape catalogues to date.

4S82z is located at the peak efficiency redshift and so occupies a unique advantage point in synergy with HSC. Over a factor of 2 gain in lensing efficiency compared to WAVES Wide and PFS.

Constraints on astrophysical parameters (galaxy bias, baryonic feedback, intrinsic alignment amplitude, etc.)
Key science goal
- galaxy-halo connection over $0.2 < z < 0.6$

Joint analysis of **gg lensing**, **galaxy clustering** and **abundance** to probe halos below the peak galaxy formation efficiency ($<10^{12} \text{M}_\odot$), which remain poorly probed by WL. 4S82z will sample lens galaxies down to $10^9$~$10^{10} \text{M}_\odot$.

Apart from halo mass, gg lensing also probes **secondary connections** between gals and halos.

**Assembly bias:** clustering of halos depends also secondary properties. Only prominent in low mass halos. 4S82z + HSC provides a powerful dataset to address this problem.

**Galaxy conformity:** gals of a given colour cluster more strongly around centrals of the same property, exist from halo scales out to a few Mpcs.
Key science goal

- galaxy-halo connection over $0.2 < z < 0.6$

Apart from extracting DM distribution around centrals, 4S82z can also enable lensing analysis of halos of satellite galaxies (subhalos).

Spec-z can be used to construct galaxy groups (with central and satellite gals).

Subhalo-satellite connection provide information on how galaxies and halos merge and how they evolve after the mergers.

Measurements of the total subhalo population at each radius constrain the fraction of tidal stripping and disruption.

R. Feldmann et al. (2012)
Key science goal
- the role of environment in galaxy and AGN evolution

Combination of wide area and dense sampling of 4S82z means we can study the role of environment on the full range of scales from cluster core to field.

Diverse cluster samples with ACT clusters selected via the thermal SZ effect, clusters selected as diffuse X-ray sources, many thousands of clusters from optical and IR imaging surveys.

Cross-calibration of total cluster mass estimates from X-ray luminosity, optical richness, SZ effect, weak lensing, and dynamical information of member galaxies.

Also galaxy-cluster lensing and cluster clustering. Provide additional cosmological constraints.

M. Hilton et al. (2018)
Key science goal
- stellar mass assembly and star formation history $0.2 < z < 0.6$

Cross-calibration of a multitude of SFR tracers: UV, Hα, OII, IR, radio, SED fitting. Provide important lessons learned for high-z studies.

J-band selection results in a more complete selection in stellar mass and SFR. Characterise the SFR distribution function down to the characteristic SFR in different environments. Provide crucial information on the SHMR and constraints on galaxy evolutionary paths.
Key science goal
- accretion history of SMBH

S82 has unique advantage in benefiting from deep and wide X-ray and IRAC coverage. Joint selection in X-ray and IRAC bands mean more complete selection in AGN.

Complement AGN selection with variability-selected AGNs, optical type 1 and type 2 AGNs, and radio loud AGNs.

Measure BH accretion and SFR in the same galaxy populations. Compare CSFH and BH accretion history in the same galaxies to test co-evolution.
Key science goal
- supermassive black hole-halo connection

AGN - galaxy cross-correlation function with orders of magnitude increase in power over AGN auto-correlation function.

Large-scale clustering AGN constrains bias factor and connection to DM halos

Small scale clustering (< 1/h Mpc) constrains halo occupation distribution and AGN fuelling and feedback.

Large statistical sample to bin in AGN luminosity, BH mass, etc. Learn the BH mass - halo mass relation.
4S82z Team

Open membership. Current members include:

Veronique Buat (LAM)
Matthieu Bethermin (LAM)
Maciej Bilicki (University of Leiden)
Denis Burgerella (LAM)
Karina Caputi (University of Groningen)
Caitlin Casey (University of Texas at Austin)
Dave Clements (Imperial College London)
Ken Duncan (University of Leiden)
Duncan Farrah (University of Hawaii)
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Carlotta Gruppioni (INAF)
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Evanthia Hatziminaoglou (ESO)

Jackline Hodge (University of Leiden)
Olivier Le Fevre (LAM)
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John McKean (University of Groningen)
Peder Norberg (University of Durham)
Seb Oliver (University of Sussex)
Giulia Rodighiero (University of Padova)
Lingyu Wang (SRON)
Julie Wardlow (University of Lancaster)
Conclusions

4S82z benefits from a plethora of ancillary multi-\(\lambda\), multi-epoch imaging and spectroscopy.

Constraints on cosmology and astrophysics utilising the superb HSC imaging data.

Connecting galaxies and SMBHs to host dark matter halos.

Galaxy and AGN evolution on the full range of environments from cluster core to the general field.

4S82z will provide important complementary science to 4MOST consortium surveys and expand legacy in Stripe 82.